ETS along the length of Cascadia

Observations and implications for seismic hazard

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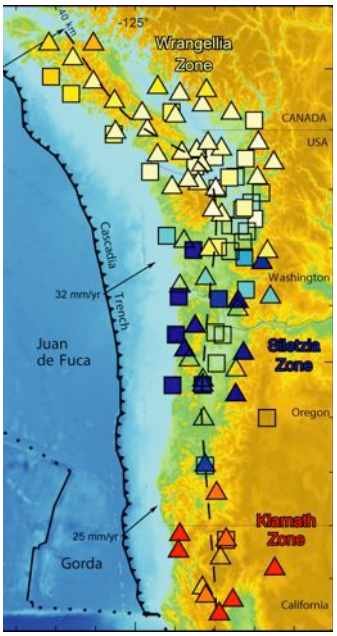
Funding provided by NSF



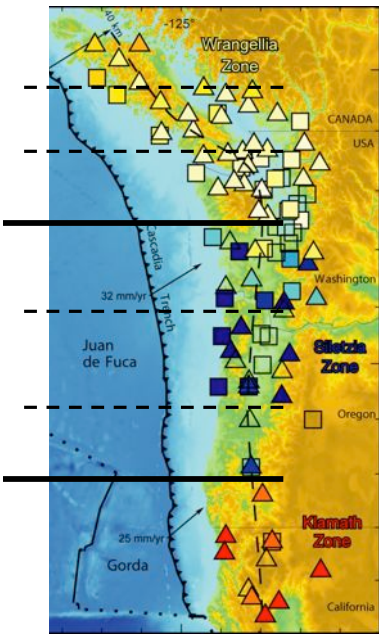
Two main points...

1. Segmentation of ETS

- **3 zones** with similar recurrence intervals
- **7 segments** which can slip independently
- **22 ETS events** from 2000 to 2006
  ➔ every 3.3 months

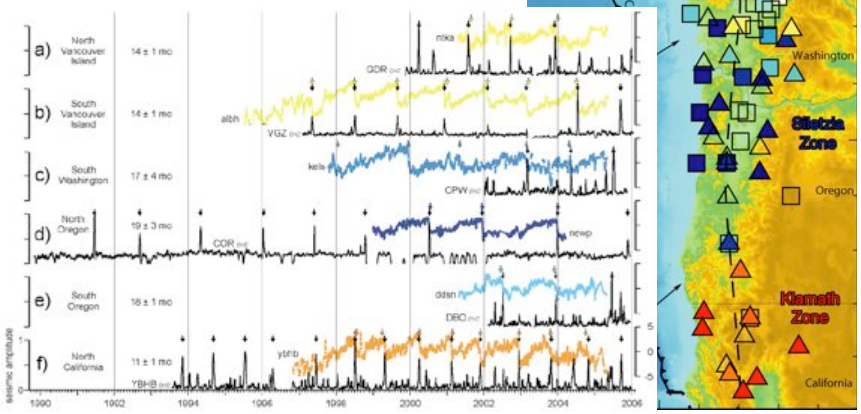
2. Structural controls

- **"Zones"** *correlate* with geologic terrain of the continental plate
- **"Segments"** *correlate* with forearc basins interpreted as indicators of megathrust structure



Tremor and slow slip

Automated detection:
- **Seismic data: tremor**
- **GPS data: slow slip events**

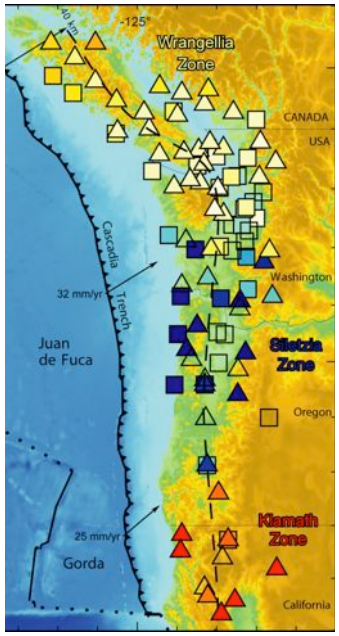


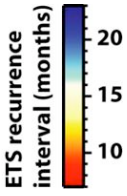
Tremor and slow slip

Automated detection:
- **Seismic data: tremor**
- **GPS data: slow slip events**

Three zones

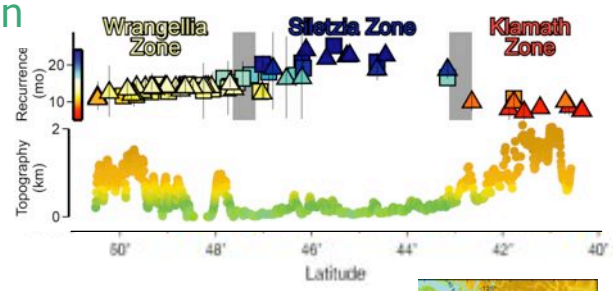
Recurrence intervals
- **14 months ±2 – Wrangellia**
- **19 months ±4 – Siletzia**
- **10 months ±2 – Klamath**

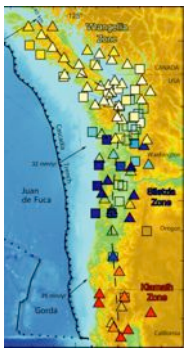




Segmentation

Three "zones"





Topography is proxy for terrain blocks

Klamath, Wrangellia: Older, more felsic, weaker

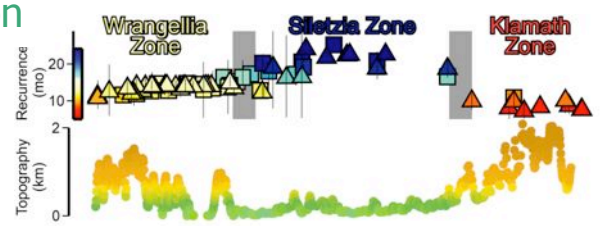
Siletzia: Younger, more mafic, stronger

➔ **Rheology may control ETS recurrence**

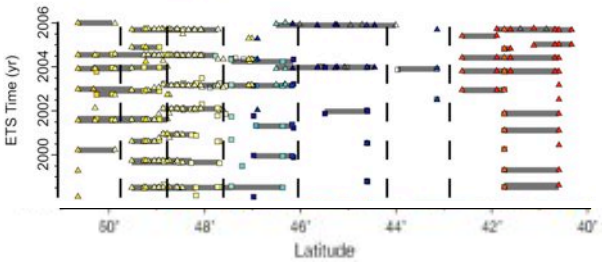
– fluids as a catalyst for ETS?

Segmentation

Three "zones"



Seven "segments"



Individual patches with the same recurrence interval but different phase

Time history

2000 to 2006

Black: ETS event

Grey
(10 months)

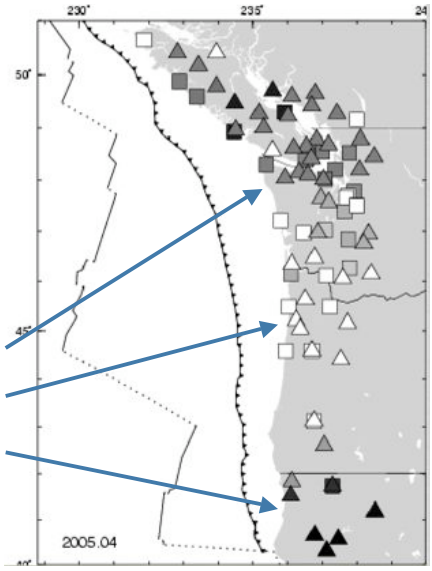
White
(20 months)

time

10 months ago

17 months ago

Most recent event



Time history

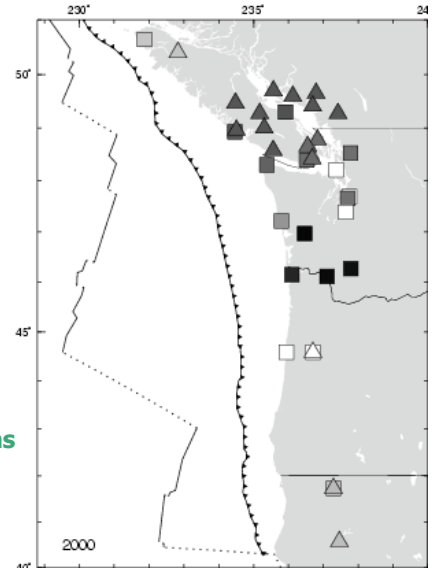
2000 to 2006

ETS events

2000	**Mar**	**Aug**	**Dec**		
2001	**Feb**	**Apr**	**Aug**	**Nov**	**Dec**
2002	**Feb**	**Dec**			
2003	**Feb**	**Oct**	**Dec**		
2004	**Apr**	**Jun**	**Jul**	**Nov**	
2005	**Jan**	**Jun**	**Sep**	**Nov**	**Dec**

➔ **22 events in 6 years**

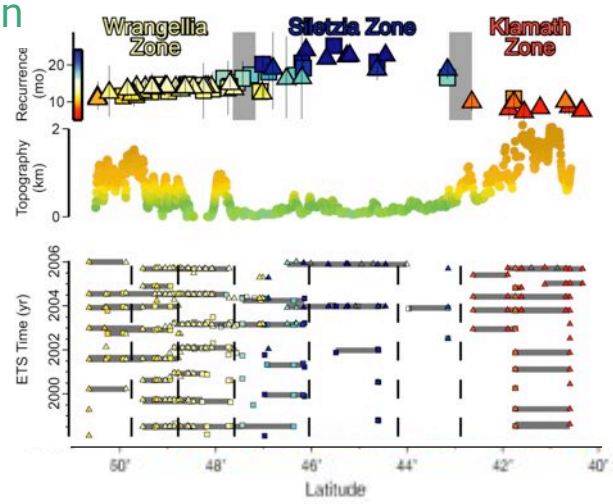
➔ **1 event every ~3.3 months**



Segmentation

Three "zones"

Seven "segments"

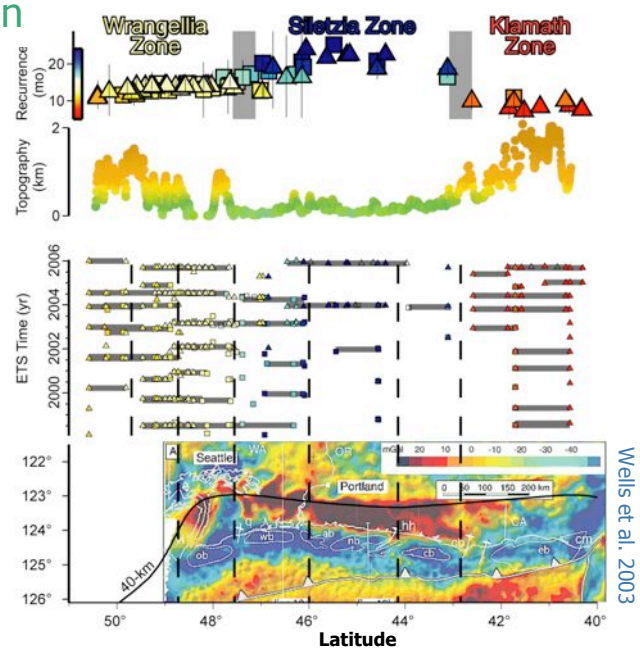


Segmentation

Three "zones"

Seven "segments"

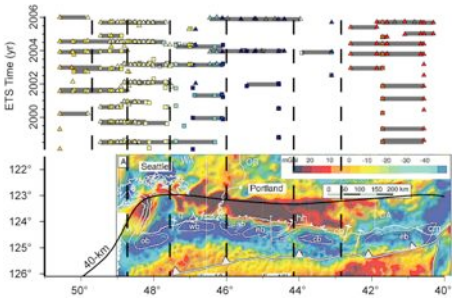
Tentative correlation with forearc basins?

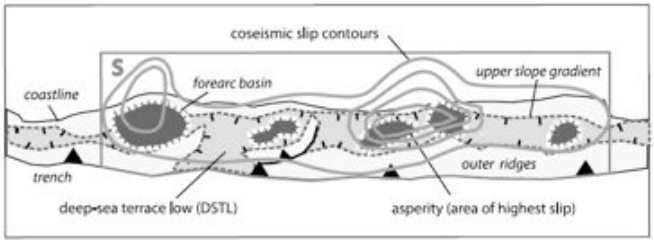


Wells et al. 2003

Forearc basins

= fault plane asperities

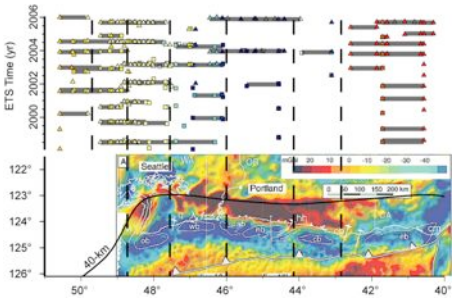


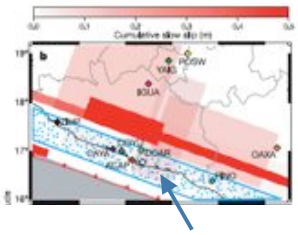


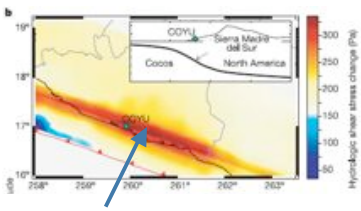
Wells et al., 2006

Numerical models

Slow slip would be favored at the base of the seismogenic zone







Seismogenic zone

Peak-to-peak shear stress

Lowry, 2006

Summary

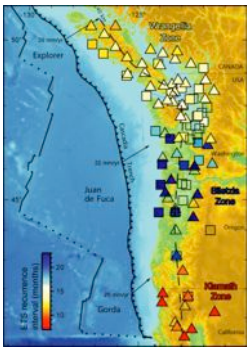
Three coherent zones with similar recurrence

– rheology of the overriding plate may be controlling; fluid content perhaps important

– younger, stronger more "oceanic" continental crust having longer hold times

Seven slip segments

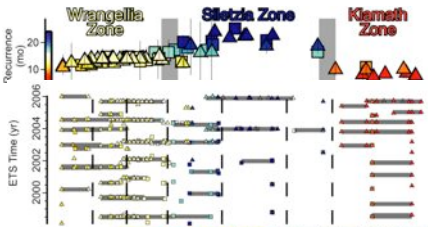
– segments may relate to seismogenic asperities



ETS events every ~3.3 months

– does each event represent increased hazard?

– of what value would such frequent seismic alerts be to the public?



Studying ETS

New seismic deployments to investigate ETS

CAFÉ

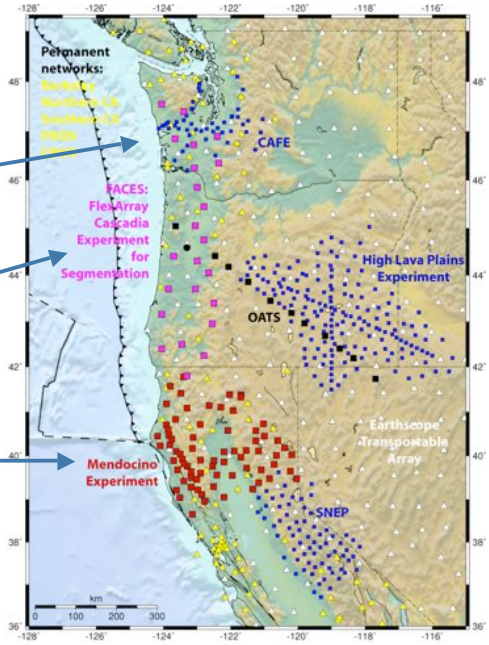
PIs: Creager, Malone, Abers, Rondeny, Melbourne

FACES

PIs: Brudzinski, Allen

Mendocino

PIs: Levander, Humphreys, Allen



ETS event table

	North						South	
	A	B	C	D	E	F	G	N events
2000	Mar							
		Aug						
			Dec					3
2001							Feb	
				Apr				
	Aug	Aug						
							Nov	
					Dec			5
2002			Feb					
	Dec	Nov					Dec	2
2003			Feb	Feb				
							Oct	
	Dec	Dec		Dec	Dec	Dec		3
2004				Apr				
							Jun	
	Jul	Jul	Jul					
		Nov						4
2005							Jan	
							Jun	
		Sep	Sep				Sep	
				Nov	Nov			
	Dec							5

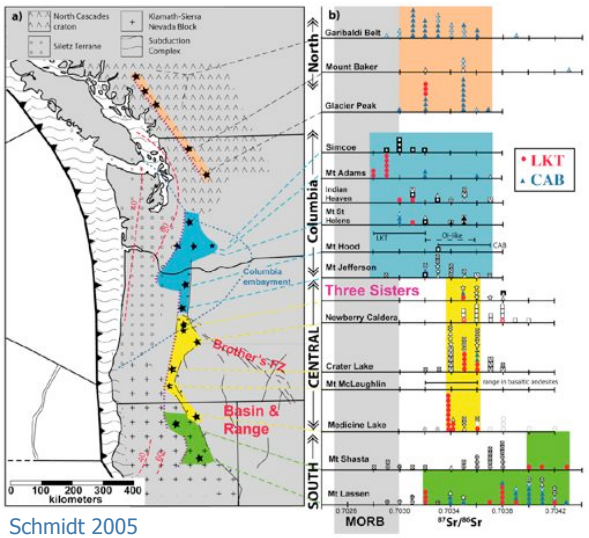
➔ 22 events in 6 years

➔ 1 event every 3.3 months

Arc segmentation – fluids

Melting

LKT → dry melting
CAB → wet melting



wet

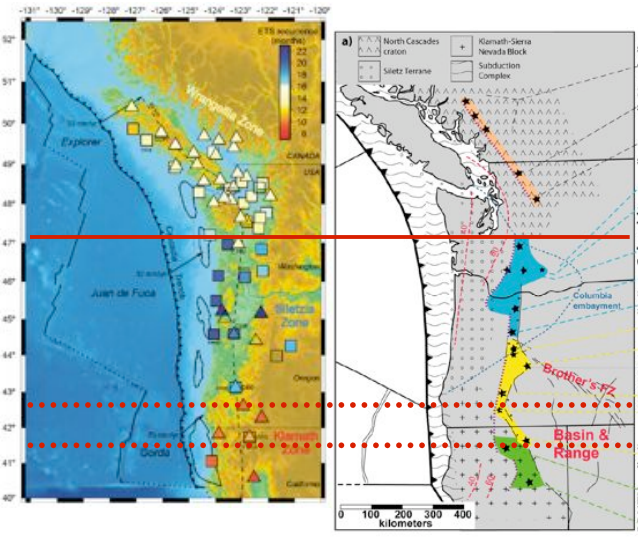
dry

dry

wetter
Shasta has highest H_20

Schmidt 2005

Arc melting and ETS



Melting

wet

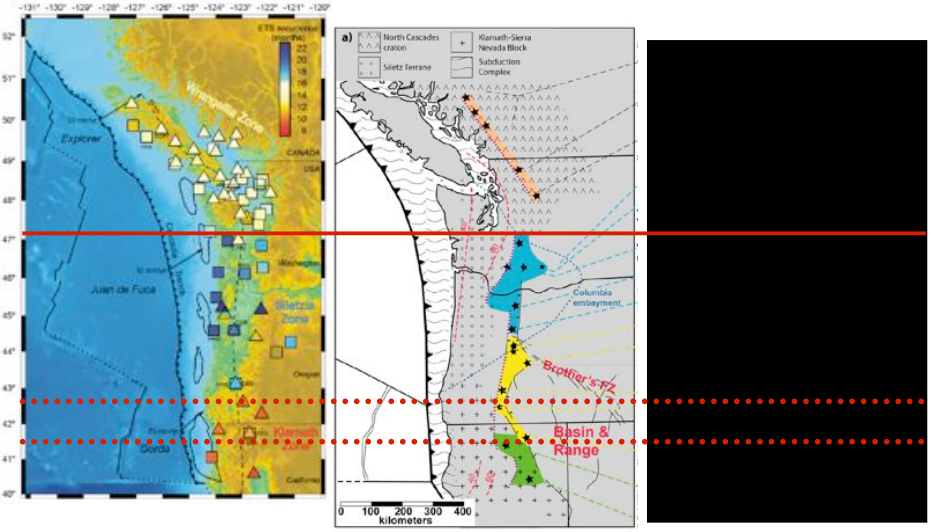
dry

dry

wetter
Shasta has highest H_20

Schmidt 2005

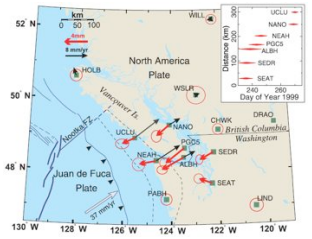
Arc melting, ETS and interface earthquakes



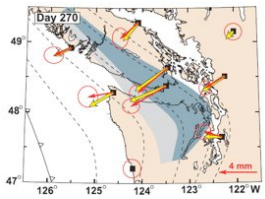
Schmidt 2005

Tremor and slow slip?

– A new view of subduction and metamorphism

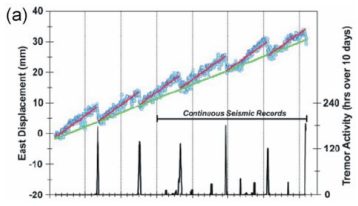


Slow slip events beneath Vancouver Island



Dragert et al. 2001

Non-volcanic tremor



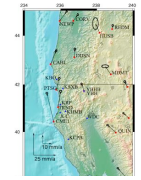
Rogers & Dragert 2003

14 month recurrence

Kao et al. 2006

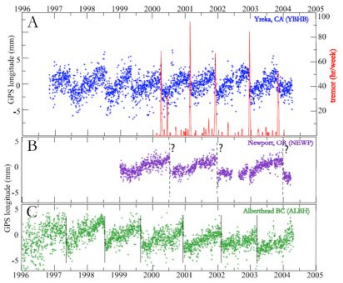
Tremor and slow slip?

– A new view of subduction and metamorphism



Episodic tremor and slip in northern California

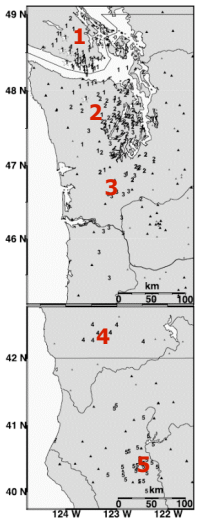
11 month recurrence



Szeliga et al. 2004

Five segments with different recurrence intervals

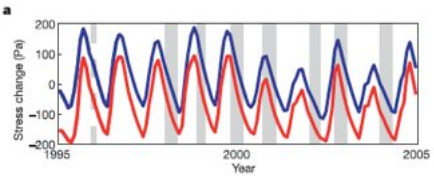
- **1:** 14 months
- **2:** independent short bursts
- **3:** 12.5 months
- **4:** one burst
- **5:** 11 months



McCausland et al. 2005

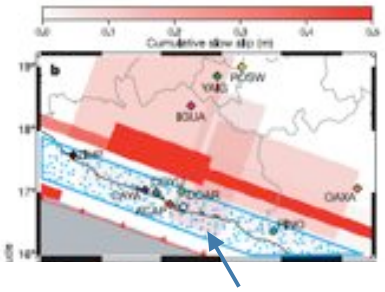
Resonant slip

at base of seismogenic zone

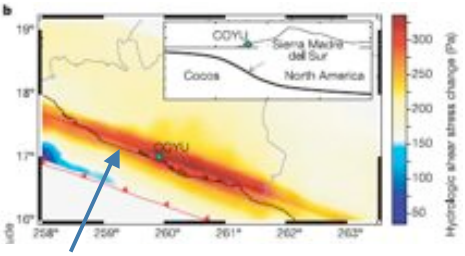


Lowry, 2006

- **Climatic loading responsible for periodic behavior of ETS**
- **Slow slip would be favored at the base of the seismogenic zone**



Seismogenic zone

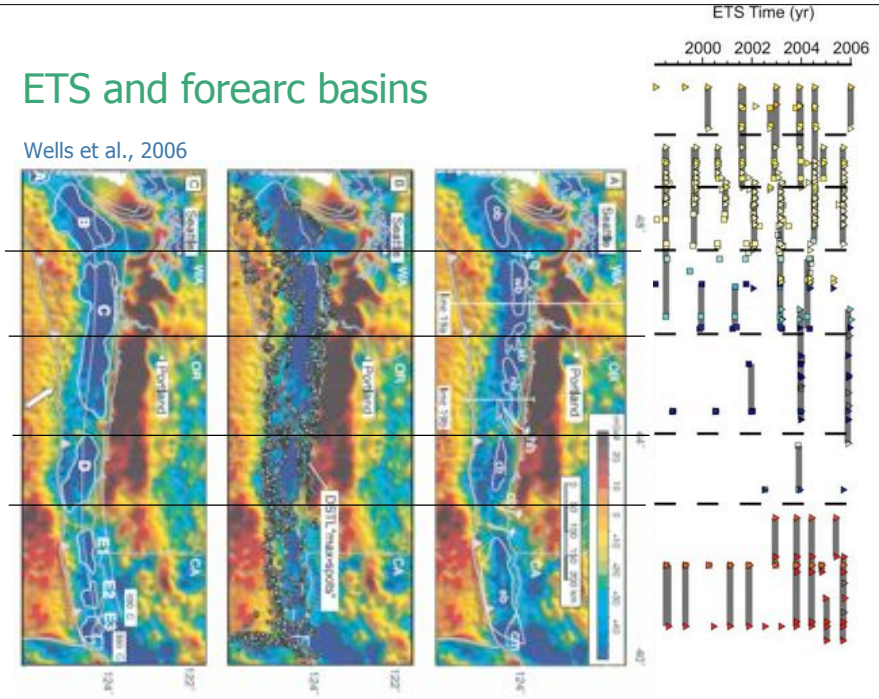


Peak-to-peak shear stress

Lowry, 2006

ETS and forearc basins

Wells et al., 2006



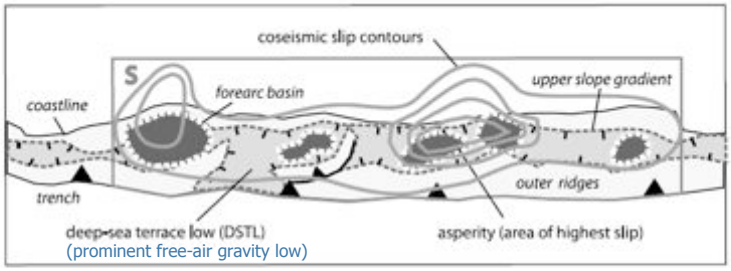
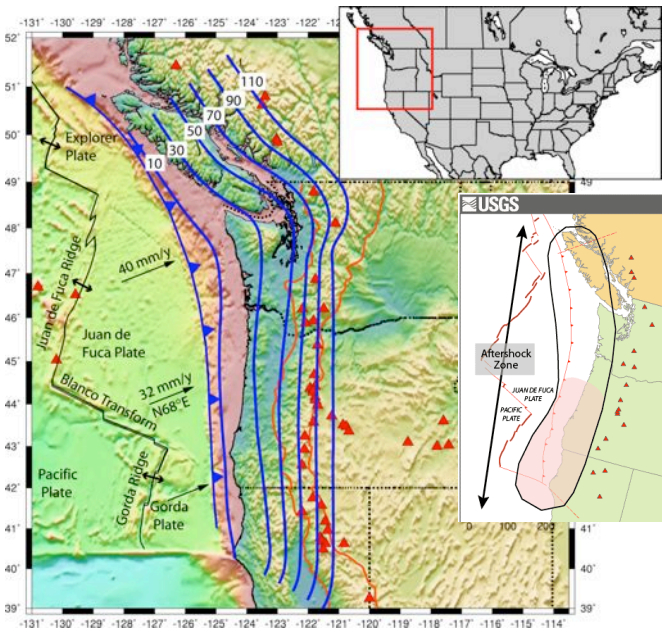


Figure 17. Subduction zone cartoon summarizing observations of 29 of the largest Circum-Pacific megathrust earthquakes. S is seismogenic zone, with downdip limit of coseismic slip from thrust focal mechanisms, thermal or geodetic models, or mantle depth. The DSTL comprises on average 41% of S but contains 71% of an earthquake's seismic moment and 79% of its asperity area (area of highest slip). Mapped forearc basins comprise 21% S and contain 57% of an earthquake's asperity area, on average.

Wells et al., 2006

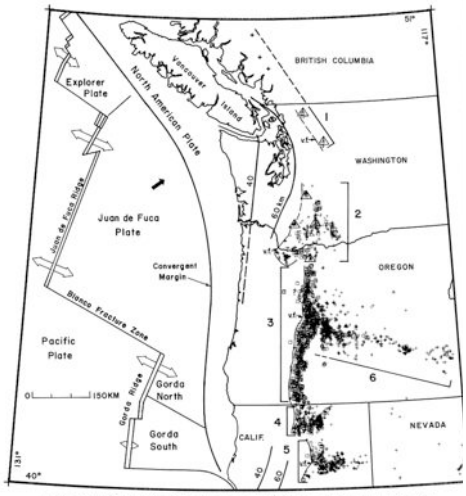
Cascadia



Slab contours from McCrory et al, 2006

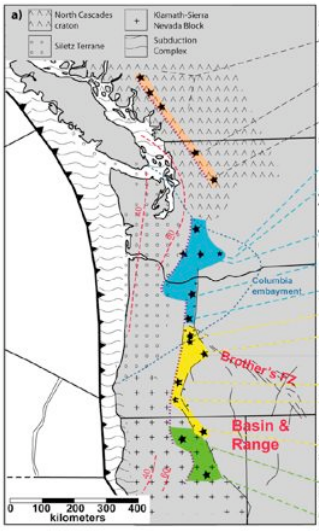
Arc segmentation

Physical (vent distribution)



Guffanti & Weaver 1988

Isotopic



Schmidt 2005

Earthquakes

– The fate of the Juan de Fuca plate

ANSS catalog
1970 – present

Slab contours
from McCrory
et al, 2006

Earthquakes

– The fate of the Juan de Fuca plate

ANSS catalog
1970 – present
Mag > 4

Slab contours
from McCrory
et al, 2006

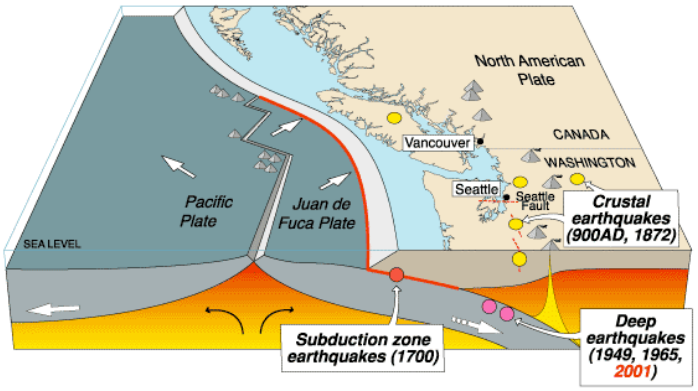
Cascad

subduction

earthquakes

volcanoes

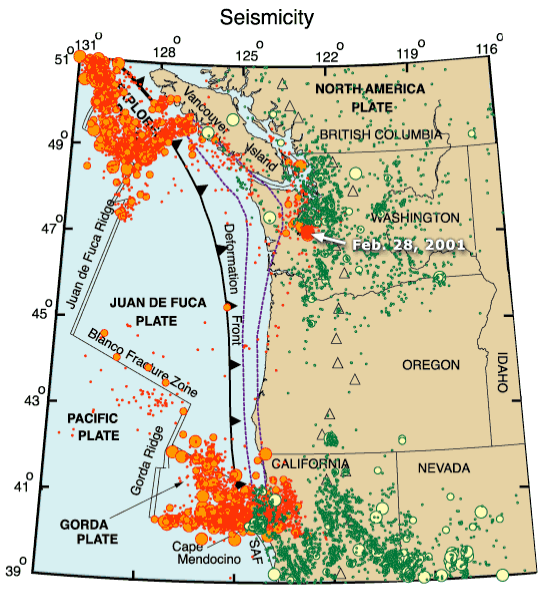
tsunamis



Source	Affected area	Max. Size	Recurrence
Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?

Cascadia earthquakes

what is the seismicity telling us?



green: crustal
orange: deep

modified from Weaver and Shedlock, 1996